# Set 38: Calorimetry

**Skill 38.01: Be able to convert from one unit of energy to another**
**Skill 38.02: Be able to define specific heat**
**Skill 38.03: Be able to calculate the energy content of an object**
**Skill 38.04: Be able to calculate the specific heat of an object**

**Date Collection**

Obtain a piece of metal from the supply cart

Fill a 400 mL beaker ½ full with water. Place the beaker on a hot plate. Turn the heat to its highest setting.

While the water is heating, determine the mass of your sample. **Record the mass of the metal.**

Determine the mass of the Styrofoam cup. **Record the mass of the cup.**

Fill a Styrofoam cup ½ full with tap water (there must be enough water to completely submerge the piece of metal). Determine the mass of the cup and water. **Record the mass of the cup + water**.

Place a thermometer in the cup of water. When the temperature has stabilized, **record the temperature of the tap water.**

Once the water in the beaker is boiling, place a thermometer in the water. When the temperature has reached a maximum, **record the maximum temperature of the hot water** (this will be about 100°C).

Remove the thermometer from the beaker of hot water and set aside.

Using tongs, gently lower the metal object into the beaker of boiling water. Continue heating until you think the object is the same temperature as the boiling water (about 5 minutes).

Using tongs, gently transfer the metal object from the boiling water to the cup of tap water.

Quickly place the thermometer in the cup of water with the object. Monitor the temperature of the water and object. The temperature will rise slightly. **Record the maximum temperature of the water + cup + object.**

Dry the piece of metal, then repeat the experiment 1 more time with the rubber stopper.

**Table 1**

| | Trial 1 - metal | Trial 2 – rubber stopper |
|---|---|---|
| Mass of object | | |
| Mass of cup | | |
| Mass of cup + water | | |
| Temperature of tap water in the cup | | |
| Max temperature of hot water | | |
| Maximum temperature of water + cup + object | | |

## Skill 38.01: Be able to convert from one unit of energy to another

### Skill 38.01 Concepts

Energy is the capacity to do something. The more energy something has, the more it can do. To forms of energy include:

- Heat
- Light

The law of conservation of energy states that energy is neither created nor destroyed. For example, when you placed the object in the cup of hot water for example, the temperature of the water decreased and the temperature of the object increased. This is because energy was transferred from the water to the object.

A **calorie** (cal) is unit of energy.

The SI unit of energy is the **joule** (J)

- 1 cal = 4.184 joule
- 1000 joule = 1 kilojoule (kJ)

**Skill 38.01 problem 1**

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| a. Convert 200. cal to joules<br>b. Convert 587 kJ to calories |
| |

## Skill 38.02: Be able to define specific heat

### Skill 38.02 Concepts

The **specific heat** (s) of a substance is the amount of heat energy needed to warm 1 g of that substance by 1 $^{o}$C. The specific heats of several substances are shown in table 1. It can also be thought of as the amount of heat released as 1 g of a substance cools by 1$^{o}$C. The greater the specific heat for a given substance, the greater the energy required to heat the substance.

Table 1. Specific Heats

| **Substance** | **cal/g-$^{o}$C** | **J/g-$^{o}$C** |
|---|---|---|
| Water | 1.000 | 4.184 |
| Iron | 0.107 | 0.449 |
| Aluminum | 0.215 | 0.901 |
| Ethanol | 0.581 | 2.43 |

The specific heat of substance is unique to that substance

### Skill 38.02 Problem 1

| Which substance in table 1 requires the most energy to heat? How do you know? |
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## Skill 38.03: Be able to calculate the energy content of an object

### Skill 38.03 Concepts

A calorimeter is a device used to measure the energy content of an object. In the lab activity, your calorimeter was just a Styrofoam cup with water. When a hot object was placed in the Styrofoam cup of water, the water warmed up. If you assume that ALL the energy from the object was transferred to the water, you now can calculate the energy content of the object so long as certain data about the water is known.

Example: A 21.00 g sample of glass was heated to a temperature of 100.0°C in a beaker of water. The glass was then transferred to a cup of water at 23.0°C. After the glass was transferred, the temperature rose to a maximum of 25°C. The mass of the water in the cup was 111.0 g. How much energy did the water absorb? How much energy did the piece of glass lose?

Solution

*Step 1*: Organize the given information

Mass object = 21.00 g
Mass water = 111.0 g
Temp of hot object = temp 100.0°C
Temp of tap water = 23.0°C
Max temp of object + water = 25°C

*Step 2*: Calculate the energy absorbed by the water

Energy water = mass of water x specific heat of water x change in temperature of water

$$q = ms\Delta T \qquad (1)$$

$$= (111.0\ g)\left(4.184\ \frac{J}{g\ ^{o}C}\right)(25.0^{o}C - 23.0^{o}C)$$

$$= 929\ J$$

*Step 3*: Calculate the energy lost by the object

It is not necessary to calculate the energy lost by the object. If one assumes that the energy absorbed by the water is equal to the energy lost by the object then,

Energy absorbed by the water = Energy lost by the object = 929 J

**Skill 38.03 Problem 1**

| Calculate the energy lost by the metal object for each trial. |
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## Skill 38.04: Be able to calculate the specific heat of an object

**Skill 38.04 Concepts**

The **specific heat** (s) of a substance is the amount of heat energy needed to warm 1 g of that substance by 1 $^{o}$C. The higher the specific heat of a substance the more resistant it is to temperature changes. The following example illustrates how to calculate the specific heat of an object using data from a simple calorimeter.

Example: A 21.0 g sample of glass was heated to a temperature of 100.0$^{o}$C in a beaker of water. The glass was then transferred to a cup of water at 23.0$^{o}$C. After the glass was transferred, the temperature rose to a maximum of 25$^{o}$C. The mass of the water in the cup was 111.0 g. What is the specific heat of the piece of glass?

Solution

*Step 1*: Organize the given information

Mass object = 21.0 g
Mass water = 111.0 g
Temp of hot object = temp 100.0$^{o}$C
Temp of tap water = 23.0$^{o}$C
Max temp of object + water = 25$^{o}$C

*Step 2:* Calculate the energy absorbed by the water

Energy water = mass of water x specific heat of water x change in temperature of water

$= ms\Delta T$

$= (111.0\ g)(\ 4.184 \frac{J}{g\ ^{o}C})(25.0^{o}C - 23.0^{o}C)$

$= 929\ J$

*Step 3*: Calculate the energy lost by the object

It is not necessary to calculate the energy lost by the object. If one assumes that the energy absorbed by the water is equal to the energy lost by the object then,

Energy absorbed by the water = Energy lost by the object = 929 J

*Step 4*: Calculate the specific heat of the object

Once the energy lost by the object is known, the specific can be determine using the following equation:

Energy object = mass of object x specific heat of object x change in temperature of object

$E = ms\Delta T$

Rearranging,

$s = \frac{E}{m\Delta T}$

In this equation, s is the specific heat, E is the energy, m is the mass and ΔT is the change in temperature.

E was determined in step 3. It is equal to 929 J.
m is the mass of the object. It is equal to 21.0 g
ΔT is the change in temperature of the object, it is equal to 100.0°C – 25.0°C = 75°C

Substituting,

$$s = \frac{929\ \text{J}}{(21.0\ \text{g})(75^{\circ}C)}$$

$$= 0.590 \frac{\text{J}}{\text{g}\cdot{}^{\circ}C}$$

The stuff on the end of this number is just units. You can cancel a J with a g or °C, so you just leave them. Always include them!

**Skill 38.04 Problem 1**

| A 22.0 g piece of metal was heated to 100°C in a beaker of boiling water. The hot piece of metal was placed in 100 g of water at 25°C. The metal and the water reached thermal equilibrium at 28°C. What is the specific heat of the metal? |
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**Skill 38.04 Problem 2**

| (a) Calculate the specific heat of the metal for both trials.<br>(b) Average the specific heats for the two trials.<br>(c) Report this value to your instructor. |
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